

Deposition and Infiltration of Absorber Materials for Solution Processable Solar Cells using Electric Field-Assisted Spray Technique

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By

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CERTIFICATE

This is to certify that the thesis entitled " Deposition and Infiltration of Absorber Materials for Solution Processable Solar Cells using Electric Field-Assisted Spray Technique" being submitted by Miss TULJA BHAVANI KORUKONDA to the Indian Institute of Technology Delhi is an ethical consideration for the award of the degree of Doctor of Philosophy and is a record of the original and bonafide research work carried out by her under my guidance and supervision. The results obtained in the thesis have not been submitted in part or full to any other University or Institute for the award of any degree/diploma.

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Abstract

Solar photovoltaics play an important role in solar energy conversion technologies. The role of solution-processable solar cells and thin film solar cells in the development of cost-effective and sustainable energy generation is significant. The major component and the process of a class of solution-processable solar cells, Dye-Sensitized (DS) and Perovskite (P) solar cells (SCs) are porous electrodes and accommodate active material in these electrodes. In this thesis, the work is focused on the infiltration of dye and perovskite material in their respective devices. Particularly, the electric field-assisted spray (e-spray) technique is proposed as a facile technique for this purpose.

The role of electric fields in the spray technique is established by studying the effectiveness of infiltration of the dye and its loading in DSSCs using e-spray and comparing the results to the conventional DSSCs. The concept of tandem photoanodes for DSSCs is discussed and existing techniques to fabricate them are evaluated. Facilitating a controlled and precise infiltration to fabrication of tandem and gradient absorbers is demonstrated by fine-tuning the experimental parameters of e-spray and tandem DSSC devices are realized. Apart from the improvement in the dye loading, which resulted in the improvement of device's current density, the e-spray technique accelerated the fabrication process from several hours to a few mins.

For the spray-deposited perovskite material, the effect of electric field on the morphology and optoelectronic properties is investigated. The e-spray technique is extensively used in lead and non-lead perovskite material infiltration in Carbon-PSCs to address the issue of the poor and non-uniform infiltration and crystallization of perovskite into complex C-PSC architectures. The prototyping and demonstration of the e-spray fabricated C-PSC are carried out using bismuth

perovskite, followed by the ink development for spray technique and fabrication of lead-based C-PSC using e-spray.

This thesis tries to fill the research gap in the domain of infiltration of absorber materials into porous electrodes and device architectures with the complex hetero-porous structure to fabricate solution-processable solar cells with an emphasis on using the e-spray technique for the same. The work demonstrates the flexibility of e-spray deposition, and it serves as an important proof of concept for the infiltration of active material for energy storage and conversion application.

सार

सौर फोटोवोल्टिक सौर ऊर्जा रूपांतरण प्रौद्योगिकियों में एक महत्वपूर्ण भूमिका निभाते हैं। लागत प्रभावी और टिकाऊ ऊर्जा उत्पादन के विकास में समाधान-प्रक्रिया योग्य सौर कोशिकाओं और पतली फिल्म सौर कोशिकाओं की भूमिका महत्वपूर्ण है। प्रमुख घटक और समाधान-प्रक्रिया योग्य सौर कोशिकाओं के एक वर्ग की प्रक्रिया, डार्ड-सेंसिटाइज़्ड (डीएस) और पेरोस्काइट (पी) सौर सेल (एससी) झरझरा इलेक्ट्रोड हैं और इन इलेक्ट्रोड में सक्रिय सामग्री को समायोजित करते हैं। इस थीसिस में, काम उनके संबंधित उपकरणों में डार्ड और पेरोसाइट सामग्री के घुसपैठ पर केंद्रित है। विशेष रूप से, इस उद्देश्य के लिए एक आसान तकनीक के रूप में इलेक्ट्रिक फील्ड-असिस्टेड स्प्रे (ई-स्प्रे) तकनीक प्रस्तावित है।

स्प्रे तकनीक में विद्युत क्षेत्रों की भूमिका डार्ड की घुसपैठ की प्रभावशीलता का अध्ययन करके और ई-स्प्रे का उपयोग करके डीएसएससी में इसकी लोडिंग और पारंपरिक डीएसएससी के परिणामों की तुलना करके स्थापित की जाती है। डीएसएससी के लिए अग्रानुक्रम फोटानोड्स की अवधारणा पर चर्चा की गई है और उन्हें बनाने के लिए मौजूदा तकनीकों का मूल्यांकन किया गया है। अग्रानुक्रम और ढाल अवशोषक के निर्माण के लिए एक नियंत्रित और सटीक घुसपैठ की सुविधा ई-स्प्रे और अग्रानुक्रम डीएसएससी उपकरणों के प्रयोगात्मक मापदंडों को ठीक-ठीक करके प्रदर्शित किया जाता है। डार्ड लोडिंग में सुधार के अलावा, जिसके परिणामस्वरूप डिवाइस के वर्तमान घनत्व में सुधार हुआ, ई-स्प्रे तकनीक ने निर्माण प्रक्रिया को कई घंटों से कुछ मिनटों तक तेज कर दिया।

स्प्रे-जमा पेरोसाइट सामग्री के लिए, आकृति विज्ञान और ऑप्टोइलेक्ट्रॉनिक गुणों पर विद्युत क्षेत्र के प्रभाव की जांच की जाती है। खराब और गैर-समान घुसपैठ और जटिल सी-पीएससी आर्किटेक्चर में पेरोसाइट के क्रिस्टलीकरण के मुद्दे को संबोधित करने के लिए कार्बन-पीएससी में सीसा और गैर-लीड पेरोसाइट सामग्री

घुसपैठ में ई-स्प्रे तकनीक का व्यापक रूप से उपयोग किया जाता है। ई-स्प्रे फैब्रिकेटेड सी-पीएससी का प्रोटोटाइप और प्रदर्शन बिस्मथ पेरोव्स्काइट का उपयोग करके किया जाता है, इसके बाद स्प्रे तकनीक के लिए स्याही विकास और ई-स्प्रे का उपयोग करके लीड-आधारित सी-पीएससी का निर्माण किया जाता है।

यह थीसिस उसी के लिए ई-स्प्रे तकनीक का उपयोग करने पर जोर देने के साथ समाधान-प्रक्रिया योग्य सौर कोशिकाओं को बनाने के लिए जटिल विषम-छिद्रपूर्ण संरचना के साथ छिद्रपूर्ण इलेक्ट्रोड और डिवाइस आर्किटेक्चर में अवशोषक सामग्री के घुसपैठ के क्षेत्र में अनुसंधान अंतराल को भरने की कोशिश करता है। कार्य ई-स्प्रे जमा करने के लचीलेपन को प्रदर्शित करता है, और यह ऊर्जा भंडारण और रूपांतरण अनुप्रयोग के लिए सक्रिय सामग्री की घुसपैठ के लिए अवधारणा के एक महत्वपूर्ण प्रमाण के रूप में कार्य करता है।

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